Imaging Spins

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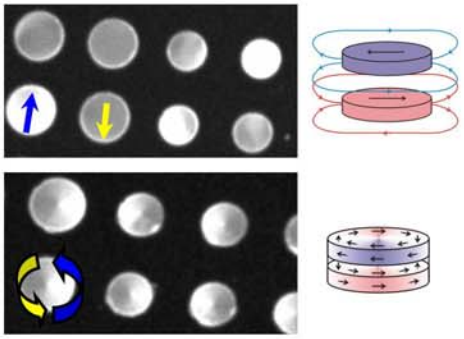
Motivation

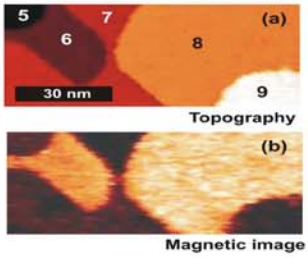
Nanomagnetism is an exciting area of research, equally important from fundamental and applied viewpoints. Understanding the behavior of geometrically confined magnetic materials relies on our ability to resolve their internal spin configurations. We employ advanced imaging tools to enhance nanomagnetism research at the Materials Science Division and strengthen our collaborative links with major users facilities.

Photo-Emission Electron Microscopy



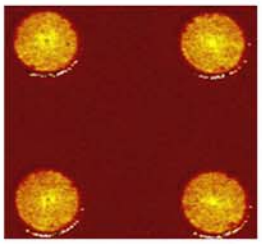
Vortex and antiparallel collinear spin states in F/N/F patterned dot arrays imaged using x-ray PEEM

Spin Polarized Scanning Tunneling Microscopy



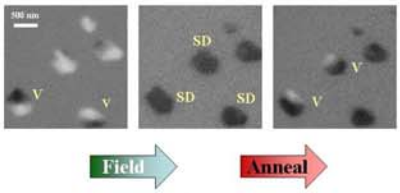
Alternating ferro- and antiferromagnetism in layer-by-layer grown Mn/Fe(001) nanoclusters revealed with SP- STM.

Magnetic Force Microscopy



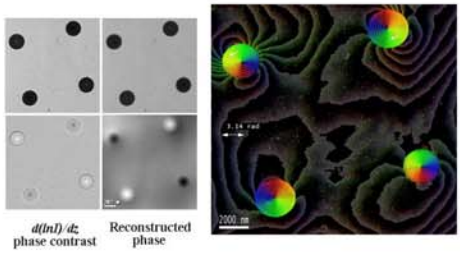
Polarization of the magnetic vortex core ("up" or "down") revealed in submicron disks using Magnetic Force Microscopy

Spin-Polarized Low Energy Electron Microscopy



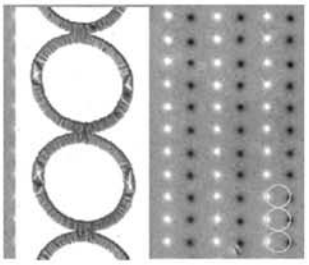
Images of various field- and temperature induced remanent magnetic states observed in Co dots grown at 780 K on Ru(0001), obtained using Spin-Polarized Low Energy Electron Microscopy

Phase-Sensitive Lorentz Transmission Electron Microscopy



Phase-sensitive Lorentz TEM is used to map the magnetic field inside and around magnetic nanostructures

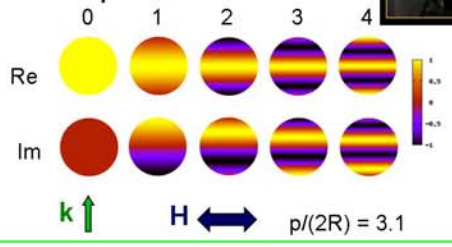
Magneto-Optical Indicator Film Imaging



Onion-like state and fine ripple spin distribution in connected ferromagnetic ring networks imaged with a Magneto-Optical Indicator Films technique (right), and Lorentz TEM (left)

Diffraction Magneto-Optics

Hysteresis loops measured using a beam diffracted from an array of nanostructures yield additional information about spatial symmetry of the magnetization reversal process



Future Directions

The Magnetic Films Group has been building a network of collaborations at major user facilities to characterize nanoscale spin behavior. Future efforts will be to develop imaging tools with spatial and/or temporal resolution that reveal new physics, such as time-resolved PEEM-3 at ALS, phase-sensitive TEM at EMC-MSD, low temperature and UHV MFM at MSD, and polarized neutron reflectometry at SNS.

S. D. Bader, "Colloquium: Opportunities in Nanomagnetism", Rev. Mod. Phys. 78, 1 (2006).

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This work was supported by the U.S. Department of Energy, Basic Energy Sciences, under contract W-31-109-ENG-38.

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